To determine the memory usage of an object, we add the amount of memory used by each instance variable to the overhead associated with each object, typically 16 bytes. The memory is typically padded (rounded up) to be a multiple of 8 bytes — an integral number of machine words—if necessary.

a. Stopwatch

The `Stopwatch` class has the following field:

- `private final long start;`

Memory usage:

- Object overhead: 16 bytes
- `long start`: 8 bytes

Total: 16 bytes (overhead) + 8 bytes (long) = 24 bytes

b. Turtle

The `Turtle` class has the following fields:

- `private double x, y;` (2 doubles)
- `private double heading;` (1 double)
- `private boolean pen;` (1 boolean)
- `private java.awt.Color color;` (1 object reference)

Memory usage:

- Object overhead: 16 bytes
- 3 `double`s: 3 * 8 = 24 bytes
- 1 `boolean`: 1 byte (padded to 8 bytes for alignment)
- 1 object reference: 8 bytes

Total: 16 bytes (overhead) + 24 bytes (doubles) + 8 bytes (boolean) + 8 bytes (reference) = 56 bytes

c. Vector

The `Vector` class has the following fields:

- `private final int n;` (1 int)
- `private double[] data;` (1 object reference)

Memory usage:

- Object overhead: 16 bytes
- 1 `int`: 4 bytes (padded to 8 bytes for alignment)
- 1 object reference: 8 bytes

Total: 16 bytes (overhead) + 8 bytes (int) + 8 bytes (reference) = 32 bytes

d. Body

The `Body` class has the following fields:

- `public Vector r;` (1 object reference)
- `public Vector v;` (1 object reference)
- `public final double mass;` (1 double)

Memory usage:

- Object overhead: 16 bytes
- 2 object references: 2 * 8 = 16 bytes
- 1 `double`: 8 bytes

Total: 16 bytes (overhead) + 16 bytes (references) + 8 bytes (double) = 40 bytes

e. Universe

The `Universe` class has the following fields:

- `private final double radius;` (1 double)
- `private final int n;` (1 int)
- `private Body[] bodies;` (1 object reference)
- `private final double dt;` (1 double)
- `private StdDraw stdDraw;` (1 object reference)

Memory usage:

- Object overhead: 16 bytes
- 2 `double`s: 2 * 8 = 16 bytes
- 1 `int`: 4 bytes (padded to 8 bytes for alignment)
- 2 object references: 2 * 8 = 16 bytes

Total: 16 bytes (overhead) + 16 bytes (doubles) + 8 bytes (int) + 16 bytes (references) = 56 bytes

Summary

Here are the revised memory usages for each class:

- Stopwatch: 24 bytes

- Turtle: 56 bytes
- Vector: 32 bytes
- Body: 40 bytes
- Universe: 56 bytes